

CENTER FOR ASTROPHYSICS IN ANTARCTICA

Center for Astrophysical Research in Antarctica (CARA)

John Carlstrom, University of Chicago.

Astronomers probe the infrared (IR), submillimeter and millimeter wavelengths of the electromagnetic spectrum in search of data that could suggest answers to some of the seminal questions about the formation of the Universe; such as:

- the formation of large-scale structure in the early Universe,
- the origin of star-forming molecular clouds,
- the origin and evolution of protostars and young stars, and
- the interaction between molecular clouds and young stars.

Antarctica is an ideal spot for such research, with its long dark winter and uniform weather conditions. The extreme winter cold (with temperatures as low as -82°C) dessicates the atmosphere, essentially removing the water vapor that complicates submillimeter-wave astronomy. These conditions make the infrared spectrum of sky above the polar plateau consistently clearer and darker than anywhere else on Earth, enabling scientists to collect measurements that would be extremely difficult or impossible from other sites.

To capitalize on these advantages, the University of Chicago and several other collaborating institutions in 1991 established the Center for Astrophysical Research in Antarctica (CARA), one of 17 Science and Technology Centers funded by the National Science Foundation. CARA's scientific mission is to investigate the conditions for astronomy at the South Pole and other sites on the polar plateau, and to establish an observatory at the South Pole. Currently, CARA supports research using three major telescope facilities:

- The Astronomical Submillimeter Telescope/Remote Observatory (AST/RO) project uses a 1.7-meter (m) diameter telescope to survey interstellar gas in the galactic plane, the galactic center, and the Magellanic Clouds.
- The South Pole Infrared Explorer (SPIREX) project uses a 0.6-m diameter telescope to observe distant galaxies, cool stars, and heavily obscured star-forming regions.
- The Cosmic Background Radiation Anisotropy (COBRA) project helps researchers test current theories of the origin of the Universe.

In addition to projects using these three telescopes, CARA's Advanced Telescopes Project collects data on the quality of polar plateau sites for astronomical observations, and configures plans for future telescopes and facilities. The following projects and principal investigators listed below are currently part of CARA. John Carlstrom, University of Chicago. (AC-370-O)

Antarctic Submillimeter Telescope and Remote Observatory (AST/RO)

AST/RO, located in the dark sector of Amundsen-Scott South Pole Station, is a 1.7-m submillimeter-wave telescope probing the electromagnetic wavelength spectrum between 200 and 2,000 microns. The telescope operates continuously through the austral winter and is being used primarily for spectroscopic studies of neutral atomic carbon and carbon monoxide in the interstellar medium of the Milky Way and Magellanic Clouds. Neutral carbon is the fourth most abundant element in the Universe. Vital to the chemistry and cooling processes of the interstellar medium, it is the only common element for which scientists can observe all variations - atomic, molecular, ionized and as graphite in dust grains.

There is a ring visible at the center of the Milky Way, about 30,000 light years away. This phenomenon is about 1,900 light years across and consists of gigantic clouds of interstellar gas, ten million times more massive than our Sun. Only by observing the spectral emissions for carbon dioxide were scientists using AST/RO recently able to confirm that the density of hydrogen remains just below the critical value that would set off gravitational processes leading to a burst of star formation.

The telescope is available to the worldwide astronomical community on a proposal basis, and many individual projects are carried out each year. In addition to ongoing maintenance, operations, and site testing, we will begin preparing this austral summer for installation of a new 1.4 THz hot-electron bolometer detector system (the TREND project). Antony Stark, Smithsonian Institution. (AC-371-O)

Automated Astrophysical Site Testing Observatory (AASTO)

Currently located a few hundred yards from the geographical south pole, AASTO is a state-of-the-art laboratory designed especially for polar work. Virtually autonomous, it powers and heats itself and harbors a half dozen instruments arrayed to assess those conditions on the high antarctic plateau that are relevant to the deployment of large telescopes. Collecting data on the electromagnetic spectrum from the ultraviolet to the sub-millimeter range, AASTO also monitors temperature, atmospheric pressure, and wind speed and direction.

By the end of the 2001-2002 field season, we will have completed almost all of our measurements at the South Pole location. The next phase entails moving AASTO to the new French-Italian station at Dome C. We also will continue to refine the AASTO power system, and

to examine alternative sources of energy. John Storey, University of New South Wales, Australia. (AC-372-O)

Degree Angular Scale Interferometer (DASI)

DASI is a 13-element interferometer designed to measure anisotropies in the Cosmic Microwave Background (CMB) Radiation - over a large range of sensitivities - and to determine its angular power spectrum. DASI's ability to provide angular coverage ($140 < l < 910$) complements the MAP satellite and other CMB experiments, and it dovetails with the VIPER telescope and the future millimeter and submillimeter capabilities it will gain through the ACBAR project.

During austral winter 2000, DASI measurements of the angular power spectrum of the CMB anisotropy over scales of 0.2 to 1.5 degrees provided a test of the inflationary model for the origin of the universe. These data also contribute a unique perspective on calculations for the total energy density and the density of normal matter in the universe. This austral summer, we will perform yearly cryogenic maintenance on the receivers in place (which operate at 30 GHz), and also plan to install new 100 GHz receivers to expand the scope for fine-scale CMB observations. John Carlstrom, University of Chicago. (AC-373-O)

VIPER Telescope

VIPER, a 2.1-m off-axis telescope, extends CARA's observations to CMB structures having smaller angular scales. It is in this range where cosmological models differ most in their predictions, and where data from VIPER should help to determine the power spectrum anisotropy. During the 2001 austral winter, VIPER hosted ACBAR - extending anisotropy observations to higher frequencies and SZE (Sunyaev-Zel'dovich effect) observations to smaller angular scales - to map fine-scale structure in the CMB and to study galaxy clusters. This austral summer we will test SPARO in preparation for future observations but will reinstall ACBAR for the 2002 austral winter. Jeffrey Peterson, Carnegie-Mellon University. (AC-375-O)

Submillimeter Polarimeter for Antarctic Remote Observing (SPARO)

SPARO, which was deployed to the South Pole in 1999, operates on the Viper 2-meter telescope. A 9-pixel, 450-micron polarimetric imager, it requires only infrequent cryogen refills, thus simplifying maintenance during the winterover. The South Pole offers superb conditions for SPARO observations, extending the reach of submillimeter polarimetry. That discipline is based on the fact that magnetic particles polarize and align perpendicular to the direction of a magnetic field. By measuring the polarization of thermal emissions from magnetically aligned dust grains, SPARO extends the study of interstellar magnetic fields to regions of low-column density that cannot be studied from other sites.

SPARO resembles polarimeters in the University of Chicago array designed for other telescopes, but those instruments (for example, at the Caltech Submillimeter Observatory and the Owens Valley Radio Observatory) provide much better angular resolution. SPARO's geographic location, however, yields a much enhanced submillimeter sensitivity to extended emissions. Giles Novak, Northwestern University. (AC-376-O)

Arcminute Cosmology Bolometer Array Receiver (ACBAR) Instrument

We plan to install the ACBAR receiver on the Viper telescope, and prepare it for winter observations. ACBAR, a 16-element, 300 mK bolometer array, will be used to map the CMBR with high-angular resolution. The instrument's wide range is designed to minimize foreground contamination, enabling it to search for distant galaxy clusters, and to measure the velocity of nearby, known clusters. Many scientists believe that the key to the CMB will be found in yet undiscovered clusters of galaxies, which ACBAR is designed to detect. William Holzapfel, University of California, Santa Barbara. (AC-378-O)